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United States Department of Agriculture
Agricultural Research Service

Report of
ANNUAL CORN AND WHEAT UTILIZATION CONFERENCE

Northern Utilization Research and Development Division
and
Corn Industries Research Foundation
Technical Committee

Peoria, Illinois
October 26, 1967

TABLE OF CONTENTS

	<u>Page</u>
SUMMARY	1
PROGRAM	3
REPORTS AND DISCUSSIONS	
Contract and Grant Research Program on Cereal Starches and Grains L. L. McKinney	4
Microscopic Structure of Starches and Proteins of Corn Genotypes . M. J. Wolf	10
Physical and Nutritional Properties of Corn Proteins J. S. Wall	11
Physical Properties of Amylose Films and Fibers Y. V. Wu	12
Interpretation of the Flow of Starch Pastes by Modified Power Law Models E. B. Lancaster	13
Gas Chromatography of Carbohydrates J. H. Sloneker	14
Zinc Starch Xanthate as a Reinforcing Agent and Vulcanization Accelerator for Rubber R. A. Buchanan	15
Dialdehyde Starch-Protein Glue for Southern Pine Plywood F. B. Weakley	16
Stress Crack Formation in Tempering Low-Moisture Corn O. L. Brekke	17
DISCUSSION	18
LIST OF ATTENDANCE	20

SUMMARY

Dr. Dimler welcomed visitors to the conference and called for a round of self-introductions. Since reports to follow constitute work which is current and continuing, further comment was deferred for the discussion period.

The Division's contract and grant research program on cereal starches and grains involving some 29 domestic and 11 foreign research projects in 7 countries was reviewed. Projects on starch include studies of structure, chemical modification, enzyme modification, and evaluation and uses of starch derivatives; structural studies on the proteins of high-lysine corn, glycoproteins of cereals, and reactions of the serine hydroxyl groups; composition and feeding value of processed corn and sorghum products; fermentation polymers; and mycotoxins. (L. L. McKinney)

Microscopic examination of the tissues of corn samples differing in genetic constitution and chemical composition reveals differences in starch and protein granule size, staining reaction, and other characteristics. Microscopy can thus serve as an aid in supporting genetic studies for which chemical analyses have been required, and it appears feasible to distinguish mechanical mixtures of high amylose and ordinary cornstarch. (M. J. Wolf)

Corn proteins, separated by classical solvent fractionation methods, were further characterized by starch gel electrophoresis and by gel filtration column chromatography. Under oxidizing conditions, formation of disulfide links is a major cause of protein insolubility, while the reductive cleavage of disulfide bonds helps explain the effectiveness of reducing agents in the corn steep. (J. S. Wall)

X-ray diffraction analyses and optical rotatory dispersion studies on amylose films and fibers cast from dimethyl sulfoxide (DMSO) solutions showed them to have a new structure, designated, "V"^{DMSO}. A direct correlation between molecular configuration of amylose in the solid state and its conformation in solution was shown. (Y. V. Wu)

Attempts to interpret the flow of starch pastes by modification of the simple power law model were not successful. Computer simulation of the integrated equations accompanied by a search routine indicated the Reiner model to be more generally useful than the power law models. (E. B. Lancaster)

Factors affecting gas chromatography of carbohydrates as the trimethylsilyl ether or acetyl ester derivatives were described. A new procedure, reduction of neutral sugars to the corresponding alditols, and chromatography of the acetate derivatives has proven simpler and more accurate. (J. H. Sloneker)

Zinc starch xanthate was evaluated as a rubber additive. At levels of addition of 6 to 25 parts xanthate per 100 parts rubber, it was found comparable to SRF black in reinforcing natural rubber and SBR, and comparable to HAF black in nitrile rubber. It also accelerated vulcanization and acted as a modifier of latex coagulation. (R. A. Buchanan)

The recently established Southern pine plywood industry has found conventional protein-based glues unsatisfactory for quality interior-grade plywood. A highly satisfactory low-cost dialdehyde starch-protein glue has been developed which in exploratory runs has been found adaptable to the typical mechanical operations employed in the industry. (F. B. Weakley)

Factors affecting the development of stress cracks in corn during conditioning for dry milling were described. With a decline of moisture from 20 to 13 percent in the corn to be tempered, there was an increase in stress cracks. Maximum stress crack formation occurred at temperatures of 65° to 85° F., with a lower rate of formation at both lower and higher temperatures. Conditioning at 125° F. resulted in no stress cracks. (O. L. Brekke)

In general discussion, continued efforts were stressed in such areas as starch granule properties, fine structure of amylose and amylopectin, characterization of new amylomaize starches, starch xanthate in paper and rubber, and microbial polysaccharides.

PROGRAM

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Introduction	R. J. Dimler
Contract and Grant Research Program on Cereal Starches and Grains	L. L. McKinney
Microscopic Structure of Starches and Proteins of Corn Genotypes	M. J. Wolf
Physical and Nutritional Properties of Corn Proteins . .	J. S. Wall
Intermission	
Physical Properties of Amylose Films and Fibers	Y. V. Wu
Interpretation of the Flow of Starch Pastes by Modified Power Law Models	E. B. Lancaster
Gas Chromatography of Carbohydrates	J. H. Sloneker
Group Photograph	
Luncheon	
Zinc Starch Xanthate as a Reinforcing Agent and Vulcanization Accelerator for Rubber	R. A. Buchanan
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Discussion	

CONTRACT AND GRANT RESEARCH PROGRAM
ON CEREAL STARCHES AND GRAINS

L. L. McKinney

A considerable portion of the research and development program of the Northern Division is carried out under domestic contracts and grants, and under foreign grants financed with Public Law 480 funds. Information obtained from this work is made available to the public through appropriate publications and patents. These are listed in our semiannual list of Publications and Patents, which is available on request.

The foreign grants provide for a limited number of final reports (usually about 50 copies) to be furnished by the grantee. We attempt to send copies to people who we feel would be interested. CIRF members have not been neglected in this distribution. After the supply of final reports is exhausted, photocopies or microfilms may be purchased from the National Agricultural Library, Washington, D.C. 20250.

The following list of contracts and grants indicates the scope of this part of our research and development program that pertains to cereal starches and grains.

Domestic Contracts and Grants

Starch Structure

1. Grant to Dr. Bertram Zaslow, Arizona State University: Studies on the helix structure of amylose.
2. Grant to Dr. R. H. Marchessault, Syracuse University: Investigation of starch fine structure by laser generated scattering patterns.

Chemical Modification of Starch

3. Grant to Dr. Roy L. Whistler, Purdue University: Basic research on preparation and characterization of glucose derivatives containing carbon-bound nitrogen, phosphorus, and sulfur.

4. Grant to Dr. Derek Horton, Ohio State University: Novel transformations of starch products leading to deoxygenated and carbon-substituted derivatives.
5. Grant to Dr. A. J. Deutschman, University of Arizona: Reactions of diepoxides with corn starch and its derived products.
6. Grant to Dr. M. L. Wolfrom, Ohio State University: Studies on amination of starch.
7. Grant to Dr. M. L. Wolfrom, Ohio State University: Reaction of vinyl ethers with glucose and starch to give acetal derivatives.
8. Grant to Dr. H. E. Hoelscher, University of Pittsburgh: Reactions of starch in a dielectric field to produce such products as levoglucosan, and starch derivatives of ammonia, ethylene oxide, sulfur dioxide, and sulfur trioxide.
9. Grant to Dr. T. D. Wheelock, Iowa State University: Basic engineering studies on the kinetics of fluid bed reactions of starches and flours.
10. Grant to Dr. J. N. BeMiller, Southern Illinois University: Preparation and properties of amylose triesters.

Evaluation of Starch Derivatives for End Uses

11. Contract with General Mills, Inc., Central Research Laboratories: Selected starch graft copolymers for use as flocculants, thickeners, sizes, adhesives, clarification of waste waters, and in beneficiation of ores.
12. Contract with Institute of Paper Chemistry: Retention of starch xanthates and xanthides on wood pulp.
13. Contract with Battelle Memorial Institute: Use of starch derivatives as protective colloids and binders in water-emulsion paints.
14. Contract with ADM Chemicals, Division of Ashland Oil and Refining Company: Use of starch-derived glycol and glycerol glycosides as protective coatings and resins.
15. Contract with University of Akron: Use of starch and starch derivatives for reinforcement of synthetic and natural rubber products.

Enzyme Modification of Starch

16. Grant to Dr. Dexter French, Iowa State University: Action patterns of bacterial amylases on starch.

17. Grant to Dr. J. A. Thoma, University of Arkansas: Mechanism of hydrolysis of starch by Bacillus subtilis amylase and sweet potato beta-amylase as model enzyme systems.
18. Grant to Dr. D. R. Lineback, University of Nebraska: Structure and formation of the carbohydrate moiety of fungal glucohydrolases active on starch.
19. Grant to Dr. B. A. Cunningham, Kansas State University: Disc electrophoresis for large-scale separation of enzymes.

Protein Studies

20. Grant to Dr. E. T. Mertz, Purdue University: Structural studies on the proteins of high-lysine corn with emphasis on disulfide bonds.
21. Grant to Dr. J. R. Vercellotti, University of Tennessee: Basic studies on the glycoproteins of cereal grains.
22. Grant to Dr. E. T. Kaiser, University of Chicago: Basic studies on reactions of the serine hydroxyl groups in cereal proteins.

Composition and Feed Studies

23. Contract with Kansas State University: Proteins, amino acids, and feeding value of hybrid grain sorghums and selected milling products therefrom.
24. Grant to Dr. Boyd L. O'Dell, University of Missouri: Interaction of phytin in processing corn and effect on feeding value with special attention to high-lysine corn.

Microbial Polymers by Fermentation of Starch

25. Grant to Dr. R. K. Finn, Cornell University: Two-phase submerged fermentation for increasing yield of product.
26. Grant to Dr. Laurens Anderson, University of Wisconsin: Fine structure of microbial polysaccharide NRRL B-1973 obtained by fermentation of starch-derived sugars.
27. Grant to Dr. W. M. Pasika, East Texas State University: Branching in starches and selected microbial polysaccharides by physicochemical techniques.
28. Grant to Dr. F. M. Rothwell, Indiana State University: Use of microbial polysaccharides for coating root systems of tree seedlings planted in strip mine areas.

Mycotoxins

29. Contract with South Dakota State University: Production of mycotoxins by species of Aspergilli grown on cereal grain substrates.

Foreign Grants with Public Law 480 Funds

(These grants are paid for with foreign currency obtained by the United States from sales of farm products abroad under Public Law 480. This money cannot be converted into dollars for use in the United States.)

Austria

1. UR-E3-(10)-6. University of Graz: Rheological studies on aqueous dispersions of modified cereal starches and paper coating formulations. 3 years, terminating 9-1-69.

India

2. UR-A7-(10)-20. Amedabad Textile Industry's Research Association: Codextrinization of cereal starch with natural gums. 5 years, terminating 1-12-68.
3. UR-A7-(10)-25. Indian Institute of Science: Separation and characterization of grain sorghum proteins. 5 years, terminating 11-1-68.
4. UR-A7-(10)-98. Amedabad Textile Industry's Research Association: Directed hydroxyethylation of starch. 5 years, terminating 6-1-70.
5. UR-A7-(10)-111. National Sugar Institute: Preparation of pure aldobi- and aldotriuronic acids to provide reference compounds. 3 years, terminating 6-25-68.

Israel

6. UR-A10-(10)-27. Hebrew University: Preparation and characterization of starch graft copolymers by reaction with vinyl monomers and epoxides. 5 years, terminating 12-1-68.
7. UR-A10-(10)-51. Institute of Fibres and Forest Products Research: Mild oxidation of starch with hypochlorite, halogen, hydrogen peroxide, and dichromate in acid medium. 5 years, terminating 11-14-68.

Japan

8. UR-A11-(10)-19. University of Osaka Prefecture: Development of a polarographic method for determination of carbonyl groups in products derived from starch. 4 years, terminating 10-1-68.

Netherlands

9. UR-E19-(10)-18. Plastics Research Institute, TNO: Preparation of metal oxides of starch for use as intermediates in synthesis of starch derivatives. 5 years, terminating 9-7-69.

United Kingdom

10. UR-E29-(10)-71. University of Edinburgh: Mechanism and structural changes involved in thermal, acid, or alkali degradation of cereal starch. 5 years, terminating 9-1-69.

Yugoslavia

11. UR-E30-(10)-1. Slovenian Academy of Sciences and Arts: Modification of cereal starches by physical treatment of granular starch to impart new paste properties. 5 years, terminating 4-11-69.

Completed Foreign Projects Under Public Law 480

*Limited number of copies of final reports available at NU

1. *UR-E9-(10)-37. Dr. Cl. Sautier, National Institute of Hygiene, Paris, France: Trypsin inhibitors in cereal flours.
2. UR-E9-(10)-40. Dr. J. Mosse, National Institute of Agronomic Research, Paris, France: Fractionation and rheology of zein from corn.
3. UR-E9-(10)-42. Dr. A. Guilbot, National Institute of Agronomic Research, Paris, France: Irradiation of starches.
4. *UR-S3-(10)-11. Dr. E. Tolmasquim, National Institute of Technology, Rio de Janeiro, Brazil: Cationic starches by introduction of phosphonium and sulfonium groups.
5. *UR-A10-(10)-1. Dr. A. Berger, Weizmann Institute of Science, Rehovoth, Israel: Grafting amino acid polymers to cereal gluten proteins.
6. UR-A10-(10)-6. Dr. M. Lewin, Institute of Fibres and Forest Products Research, Jerusalem, Israel: Kinetics and mechanism of the mild oxidation of starches with hypochlorite, hypobromite and their mixtures under alkaline conditions.

7. *UR-E15-(10)-25. Dr. Angello Mangini, Institute for the Study of Applied Industrial Chemistry, Bologna, Italy: Preparation and properties of surfactants from dextrin-fatty acid derivatives.
8. *UR-E15-(10)-32. Dr. M. Reggiani, "Giuliana Ronzoni" Institute, Milan, Italy: Conformation of the anhydroglucose ring in starch.
9. *UR-E29-(10)-36. Dr. W. A. P. Black, A. D. Little Research Institute, Edinburgh, Scotland: Basic studies on the polymerization of glucose derivatives to high molecular weight polymers.
10. *UR-E29-(10)-37. Dr. C. R. Jones, Research Association of British Flour-Millers, St. Albans, England: Basic studies on conditioning wheat for optimum milling.
11. *UR-E29-(10)-39. H. F. Martin, Research Association of British Flour-Millers, St. Albans, England: Isolation and characterization of the natural antioxidants in oats.
12. UR-E29-(10)-40. Dr. G. A. Gilbert, University of Birmingham, Birmingham, England: Studies on the structure of starch through the use of enzymes.
13. UR-E29-(10)-69. Dr. W. J. Whelan, University of London, London, England: Application of enzymes to study the fine structure of starches. (Final Report not yet received.)

MICROSCOPIC STRUCTURE OF STARCHES AND PROTEINS OF CORN GENOTYPES

M. J. Wolf

Endosperm starch characteristics, subcellular protein composition, and kernel histology are under genetic control in maize. Starch granules stained with iodine show polarization colors which are characteristic of the corn genotype from which the starch was derived. High amylose starch granules show a red polarization color while ordinary, low amylose starches show a deep blue polarization color; it is possible to distinguish the two types of starches in mixtures by observing the polarization colors. The recessive genes, opaque-2 or floury-2, control deposition of subcellular endosperm protein which is deficient in zein bodies; the resulting protein is relatively high in lysine. Although the aleurone is normally a single-celled layer of tissue, the number of cell layers making up the aleurone is apparently under genetic control. An exotic strain of maize is described in which the aleurone is two or possibly three cell layers thick. Aleurone layer protein has a relatively high content of lysine and other basic amino acids.

PHYSICAL AND NUTRITIONAL PROPERTIES OF CORN PROTEINS

J. S. Wall

Changes in harvesting methods and development of new corn varieties are causing the corn milling industry to give greater consideration to corn proteins. The proteins influence milling efficiency and nutritional value of byproducts.

The classification of corn proteins proposed at the turn of the century by Osborne based on solvent fractionation is still valid, even though fractionation is not clean-cut. These protein fractions differ in amino acid content and electrophoretic mobility in starch gel of their component proteins. In normal corn endosperm, alcohol-soluble zein predominates (42 percent). The alkali-solubles (glutelin), salt-solubles (globulins), and water-solubles (albumins) constitute 39, 2, and 3 percent of the proteins, respectively. In opaque-2 corn mutants the relative amount of zein is decreased which accounts for the increased lysine content. Yields of water-soluble proteins are reduced by artificial drying.

The albumin, globulin, and zein fractions of corn each consist of a number of different proteins as determined by starch gel electrophoresis. A partial fractionation of these proteins has been obtained by gel filtration column chromatography. This technique separates proteins on the basis of size and shape. Albumin proteins maintained at pH 8 seem to contain larger amounts of high molecular weight aggregates than does protein kept in acid solutions. Evidence was obtained that formation of disulfide links between protein molecules is a major factor causing protein insolubility.

The glutelin protein consists of high molecular weight molecules whose polypeptide chains are linked by disulfide bonds. The disulfide bonds may be cleaved by reaction of the protein with reducing agents. The resulting smaller chains of amino acids migrate during gel electrophoresis like reduced globulin and zein proteins. On moving boundary electrophoresis the native glutelin is heterogeneous and appears to consist of separate high molecular weight crosslinked globulin and zein constituents. It is believed that glutelin constitutes the matrix protein which holds the starch granules together. These observations help explain the effectiveness of reducing agents in steeping grain prior to wet-milling.

PHYSICAL PROPERTIES OF AMYLOSE FILMS AND FIBERS

Y. V. Wu

A new crystalline form of amylose is obtained when amylose films are cast from dimethyl sulfoxide (DMSO) solutions. Stretched fibers of these films gave oriented x-ray diffraction diagrams which were used to determine that the molecular configuration of the amylose is helical, with six glucose residues per turn of the helix and a repeat distance of 8.1 Å along the c axis. The helices pack in a square array with $a_0 = b_0 = 19.2$ Å and show orthorhombic symmetry. The structure is called "V"_{DMSO}. Oriented amylose fibers in the V form and complexes of amylose with n-butanol were prepared. n-Butanol complexes and V form exist in both hydrated and anhydrous forms. Their unit cells' dimensions and space groups were determined from x-ray analyses. Optical rotatory dispersion studies on amylose films show that there is a direct correlation between the structure of amylose in the solid state and its conformation in solution. The specific rotation of amylose V_{DMSO}, amorphous, and alkali films is the same as that of amylose in corresponding solutions of DMSO, 0.5 M KCl and alkali. The rotation of amylose B films is higher than that of the amylose V or amorphous films, and from infrared measurements on the films, this is attributed to the presence of inter-molecular hydrogen bonds between adjacent amylose chains in the B conformation. In general, the higher rotation of the amylose B films seems to be directly proportional to the amount of crystalline B structure in the films.

INTERPRETATION OF THE FLOW OF STARCH PASTES
BY MODIFIED POWER LAW MODELS

E. B. Lancaster

Modification of the simple power law by adding a third parameter is not sufficient to provide a fit for all starch pastes. In general, starch pastes require a parameter which represents a zero shear yield stress, whereas gums conform to a model which has a zero shear viscosity. Computer simulations of the integrated equations together with a search routine provides evaluation of the parameters. Data from measurements with a Brookfield viscometer were analyzed. The Reiner model appears to be more generally useful than power law models. Data for analysis should probably be taken under conditions closely simulating actual intended use.

GAS CHROMATOGRAPHY OF CARBOHYDRATES

J. H. Sloneker

Gas chromatography of carbohydrates is readily achieved by use of the volatile and thermally stable O-trimethylsilyl ether and O-acetyl ester derivatives. However, when sugars liberated by acid hydrolysis of natural products are quantitatively measured as the trimethylsilyl ether derivative, the analytical results can be grossly affected by the acid used for hydrolysis and the method used for neutralizing the acid before derivatization. Also, degradation products formed during hydrolysis may interfere with quantitative trimethylsilylation. Yet under properly controlled conditions the trimethylsilyl derivative affords an excellent means for quantitating hexosamines. For the neutral sugars, quantitative reduction to the corresponding alditols and chromatography as the alditol acetate derivative eliminates many difficulties encountered with the trimethylsilyl ether and provides a simple, accurate method of analysis.

ZINC STARCH XANTHATE AS A REINFORCING AGENT AND
VULCANIZATION ACCELERATOR FOR RUBBER

R. A. Buchanan

Starch xanthate was evaluated as a modifier of latex coagulation, a rubber reinforcing agent, and an accelerator of vulcanization. Mixtures of starch xanthate with degree of substitution (D.S.) 0.07 and elastomer latices were coprecipitated with zinc sulfate. The coprecipitated curd, from mixtures containing more than 6 parts starch xanthate per 100 parts of rubber (phr), had as its continuous phase the insoluble zinc starch xanthate. The curd was easily dewatered and dried. Milling of dried coprecipitate reversed starch and rubber phases and gave a uniform dispersion of fine particles of starch xanthate in the rubber. The zinc starch xanthate in these masterbatches accelerated sulfur vulcanization in proportion to the level of incorporation. Tensile properties of vulcanizates showed that zinc starch xanthate served as a reinforcing agent for a variety of elastomers. It was comparable to SRF black in reinforcing natural rubber and SBR up to 25 phr loading. In nitrile rubber it was comparable to HAF black up to 25 phr loading.

The interesting and potentially practical applications for starch xanthate discovered in these exploratory studies warrant more detailed investigations. Further research is being directed toward developing these applications for starch xanthate and other starch derivatives in rubber technology.

DIALDEHYDE STARCH-PROTEIN GLUE
FOR SOUTHERN PINE PLYWOOD

F. B. Weakley

A low-cost dialdehyde starch-protein glue has been developed for possible use in the manufacture of interior-grade Southern pine plywood. Accelerated testing in the laboratory and actual weather testing of interior pine plywood test panels prepared with the glue indicate highly satisfactory glue bond performance. Failure of conventional protein-based plywood glues to provide quality interior-grade pine plywood glue bonds is primarily responsible for the new Southern pine industry's current practice of manufacturing all plywood with the more expensive phenolic resin glues.

Brief exploratory plywood mill runs have been made with our new glue. Except for a change to a more effective antifoam agent, the glue has been found to be adaptable to the typical mechanical operations employed in pine plywood manufacture.

Evaluation of the glue in plywood mill operations is being continued.

STRESS CRACK FORMATION IN TEMPERING LOW-MOISTURE CORN

O. L. Brekke

Corn of 15 percent or less moisture often fails to give the desired improvement when tempered under typical conditions used in the dry-milling process. Such corn develops stress cracks during tempering at room temperature. Corn kernels having stress cracks break readily and do not respond properly to degermination. In laboratory studies, stress crack formation varied with initial moisture content of the corn (yellow dent hybrid) and with moisture level, time, and temperature during tempering. In a 2-hour temper with 8 percent moisture added, kernels having stress cracks increased from between 0 and 5 percent to more than 60 percent as the initial moisture content decreased from 20 to 13.5 percent. For periods beyond 1 hour for tempering 13.5 percent moisture corn, stress crack formation increased progressively as the tempered corn moisture level increased from 15 to 24 percent. The highest rate of stress crack formation occurred between 1/2 and 2 hours of tempering and at temperatures of 65° to 85° F. At lower temperatures, the rate was slower but stress cracks developed to the maximum. At temperatures above 85° F., both rate and extent of stress crack formation fell off and essentially no stress cracks were formed at 125° F. The stress cracks apparently originate in the horny endosperm. Related research indicates that during the sorption of added moisture in 13 percent corn, swelling stresses occurring within the endosperm develop forces estimated at several thousand pounds per square inch. These forces diminish rapidly as initial moisture content of the corn increases. In comparison with cold tempering in the dry-milling process, hot tempering of low-moisture corn increases the yield of large grits, reduces their oil content, and lowers the degerminator throughput.

DISCUSSION

In opening the general discussion, Dr. Dimler expressed the appreciation of the Division to the Corn Refiners Association for the research grant. We have not been able to replace Mr. Zobel or Mrs. Hinkle on the x-ray work on amylose and amylose films, but Dr. Fred Dintzis is studying optical rotatory dispersion of different corn genotypes.

Dr. Senti commented on the research presentations as a sampling of the cereals research program of the Division and led further discussion. It is apparent from Mr. McKinney's report that we are making extensive use of outside expertise in U.S. industry and abroad as well as our in-house talent. It has been traditional that CIRF has given its greatest support to "basic" research of the type coming out of these research projects.

Comments by visitors and Northern Division staff members brought out a number of areas where there is need for continuing or new information. The list of possible topics submitted by the CIRF Technical Advisory Committee, which formed the basis of the program for this meeting, indicates the need for present projects to be extended or new ones written in such areas as starch granule properties, fine structure of amylose and amylopectin, characterization of new amylomaize corn hybrids and high-amylose starches, correlation of film properties with properties noted in HA starches, interactions of organic ions with starch and of fillers with starch and effects of such interactions on film or coating properties (e.g. clay and starch in paper coatings), effect of residual protein in refined starch, and protein included in the starch granule.

Research is losing some glamour. Dr. Senti pointed out that money is hard to get and must be justified in terms of benefits. We cannot lose sight of the function of the Laboratory--to keep agricultural products competitive. If this industrial group can show a need for certain information, we can better justify doing it.

Some lines of research further discussed by Committee Members and NU staff which show promise or should be investigated: starch xanthate in rubber, dialdehyde starch-soybean flour plywood glue, microbial polysaccharides, permanent finishes for textiles based on starch, industrial uses for corn sirups.

Dr. Senti commented on world food problems and projected needs for cereals. With India as an example, he traced historical trends in production with increases of 2.5 percent per year. He compared this with trends if moderate (3 percent) and rapid (4 percent) increases can be attained and cited their effects on acreage of grain to be grown and the need for imports, assuming population increases can be held to present rates.

Some favorable comments were made by Committee Members on the value of reports from PL-480 research and availability of reprints as indicated in the semiannual lists of publications and patents. The classification and separate listing of grants, contracts and foreign research is helpful, but author and institution indexes were suggested as aids in making the transition between projects described in Multiple-Use Reports and citations in the Lists of Publications and Patents.

Mr. DeWitt expressed the appreciation and satisfaction of the Committee with the meeting and suggested that they should be continued again on an annual basis with a date in October preferable to the former spring dates.

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Attendance List

CORN INDUSTRIES RESEARCH FOUNDATION, Washington, D.C.

William G. De Witt, Vice President, Utilization and Research Development

CORN REFINERS ASSOCIATION, Washington, D.C.

Robert C. Liebenow, President

CLINTON CORN PROCESSING COMPANY, Clinton, Iowa

J. M. Newton
R. V. Mac Allister
N. E. Lloyd

A. E. STALEY COMPANY, Decatur, Illinois

J. A. Bralley
E. E. Fisher

NATIONAL STARCH AND CHEMICAL CORPORATION, Plainfield, N.J.

C. G. Caldwell
M. W. Rutenberg
O. B. Wurzburg

CORN PRODUCTS COMPANY, MOFFETT TECHNICAL CENTER, Argo, Ill.

John D. Garber
E. F. Paschall

AMERICAN MAIZE-PRODUCTS COMPANY, Roby, Indiana

C. H. Hullinger
E. L. Powell

ANHEUSER-BUSCH, INC., St. Louis, Missouri

B. L. Scallet

HERCULES INC., Wilmington, Delaware

J. A. Harpham

HUBINGER COMPANY, Keokuk, Iowa

Waldean Rapp

J. M. Seitz

UNION STARCH AND REFINING CO., INC., Granite City, Illinois

R. E. Pyle

PENICK AND FORD LIMITED, Cedar Rapids, Iowa

Murray Senkus (R. J. Reynolds Tobacco Company, Winston-Salem, N.C.)

K. W. Kirby

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Washington, D.C.

F. R. Senti, Deputy Administrator, NCIUR

NORTHERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION

R. J. Dimler

V. L. Davison

L. L. McKinney

H. M. Teeter

D. L. Miller

J. E. Hubbard

W. C. Schaefer

C. A. Moore

Cereal Products Laboratory

C. E. Rist

R. A. Buchanan

F. B. Weakley

C. R. Russell

C. L. Mehltrittter

F. H. Otey

G. G. Maher

J. C. Rankin

Cereal Properties Laboratory

J. S. Wall
J. A. Rothfus
C. W. Blessin
D. Christianson
J. W. Paulis
J. E. Hodge
H. B. Sinclair
W. E. Dick
Y. V. Wu
H. C. Nielsen
A. C. Beckwith
F. R. Dintzis
C. James
J. H. Sloneker
M. J. Wolf
U. Khoo
H. L. Seckinger

Engineering and Development Laboratory

E. L. Griffin
V. F. Pfeifer
E. B. Lancaster
O. L. Brekke
R. A. Anderson
L. A. Weinecke
H. F. Conway

Industrial Crops Laboratory

I. A. Wolff
T. K. Miwa

